Towards

21st CENTURY SKILLS

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PEDAGOGICAL INSIGHTS FOR

DIGIFOR

TEACHERS

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DIGIFOR – Digital Forest Pedagogy

The programme called South-East Finland – Russia CBC 2014 – 2020 funded by the European Union, the Russian Federation and the Republic of Finland, aims to promote cross border cooperation across the borders between EU Member State Finland and the Russian Federation. One of the priorities of the programme is "Innovative, skilled and well-educated area".

The theme "Support to education, research, technological development and innovation" bases on the need to increase the level of education among youth and elderly people. The society is changing and there is demand to update the education and lifelong learning. All stages of education enables opportunities to get employment, and often reduces the risk of social exclusion. Through education and research, the programme can promote internationalization of both persons and companies.

The DIGIFOR- project aims to increase the skills and competences of future workforce in the forest sector in the programme regions of South-East Finland, Leningrad Region and the City of St. Petersburg in Russia. The partnership includes four Higher Education Institutions: South-East Finland University of Applied Sciences, St. Petersburg State Forest Technological University, St. Petersburg State University of Industrial Technology and Design, and University of Eastern Finland.

One of the outcomes of the project is this publication "Towards 21st Century Skills – Pedagogical Insights for DIGIFOR Teachers" delivered by the researchers of the University of Eastern Finland. While the DIGIFOR project's teachers are creating and developing elearning modules for the study courses exciting in the curriculums, the publication supports the teachers in the development of higher education pedagogies and course design. There is a possibility to meet the needs of future working life better and more prepared when the 21st Century Skills have been taking into account in course design.

The publication is a tool not only for the teachers in the DIGIFOR project, but also for all the educators no matter of the field of the study or a stage of education. The example course "Collaborative Problem Solving in Multidisciplinary Networks" gives a concrete example how the theory is implemented in practice.

DIGIFOR PEDAGOGICAL COURSE DESIGN

Name of the course:

Aim of the course and how do the assignments support students to achieve them:

Participants of the course, length, course forms (e.g. online, blended, f2f):

Assessment of the course:

Description of each assignment	**Learning objectives of the assignment**	**Social arrangements** (e.g. individual work, group work, whole class discussions)	**Tools and technologies afforded**	**Role of the teacher**	**Assessment of the assignment** (e.g. test, self-assessment, peer-assessment)

1. INTRODUCTION TO 21st CENTURY SKILLS

The 21st century calls on us to solve some of the most challenging problems ever created and faced by humankind, such as climate change, loss of biodiversity, globalization, extreme poverty, population growth, inequality, and food as well as water safety. Moreover, many of these wicked problems are interconnected, networked by nature and driven by digitalization. At the same time, information and communication technology (ICT) is also transforming the ways that work is conducted. Study after another have forewarned of changes in labor needs, as many of the jobs for routine production workers – such as assembly line workers– will probably disappear as technology takes over repetitive tasks [1], [2]. Nowadays, automation is also rapidly penetrating knowledge work sectors, which for long were believed to be relatively safe from automation [1].

In addition, society not only faces changes in the work life and job markets, but a major challenge is that young people need to be educated for jobs that do not yet exist [2].

In response to global challenges compounded by the pace of automation, diverse governmental, business and non-profit organizations have begun to create strategies that pursue new competences – often referred to as 21st century skills. Several frameworks for defining these skills have been proposed and at their core, they share some similarities that enable synthesizing them in order to reach a larger-scale idea of what 21st century skills are about [3]. For example, when reviewing different twenty-first-century frameworks, Binkley et al. [4] found 10 skills and grouped these skills into four categories (figure 1).

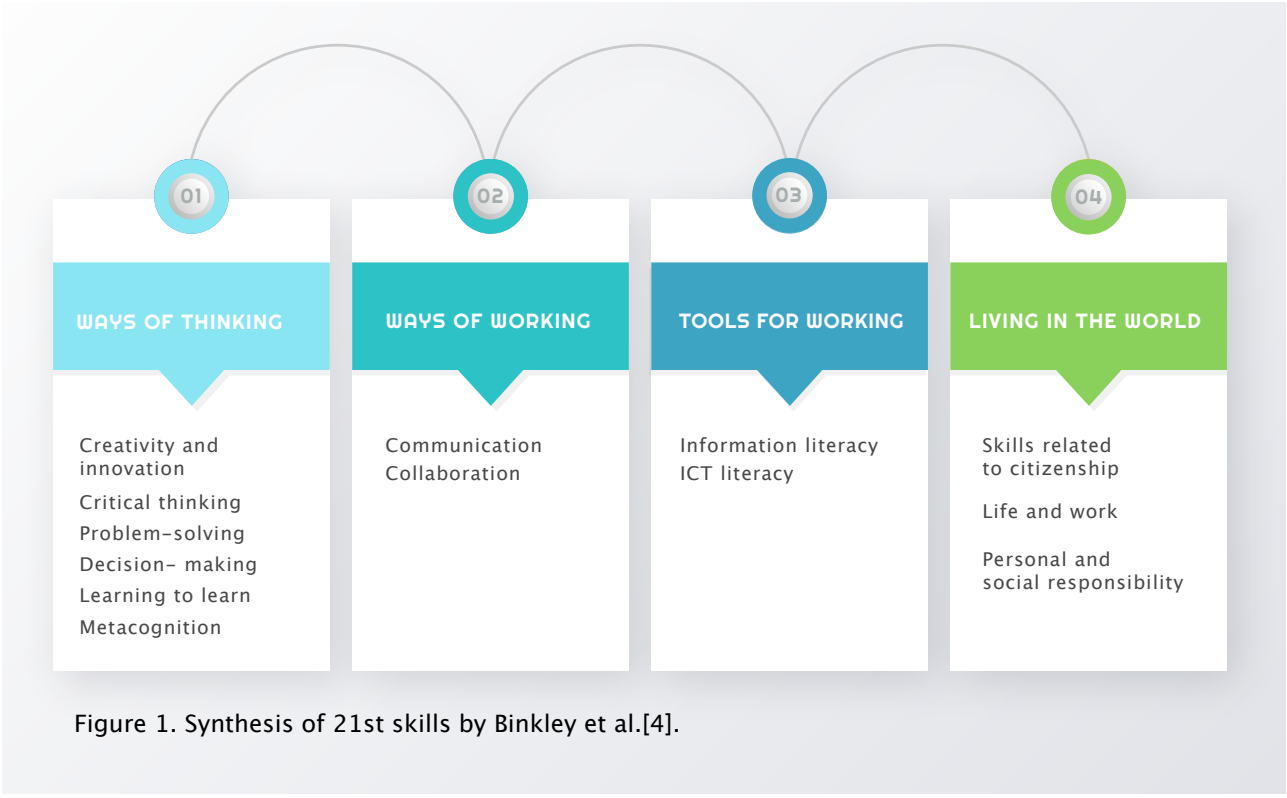
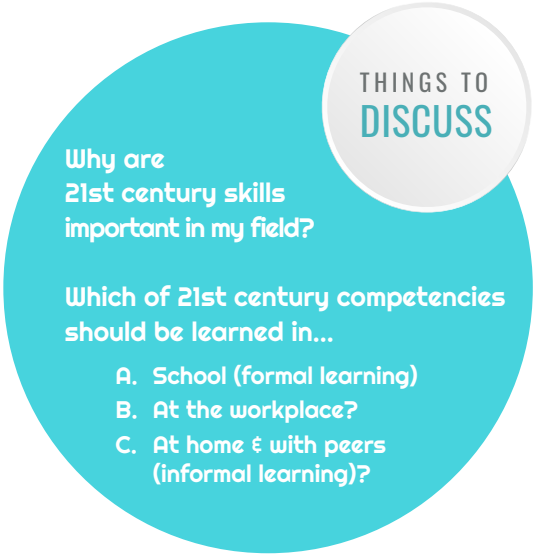


Figure 1. Synthesis of 21st skills by Binkley et al.[4].

Some frameworks also stress the changes in the economy and the labor market caused by globalization as one of the important driving forces for the need of 21st century skills [5]. Nowadays, many companies and public sector organizations have also begun to design and create new products, interfaces and services through cross-boundary teaming and knowledge creation [6]. Much of this intense interest is driven by the recognition that the vast majority of innovations and business-development opportunities lie in the interfaces between knowledge boundaries – boundaries associated with differences in expertise and organizations [6]. As such, the next generation of workers will need to have a deep understanding of at least one domain, but they also need to become fluent in collaborating and learning with diverse field experts, stakeholders, decision makers, producers, and end users [7]. However, researchers are also concerned that there is an increasing gap between such knowledge work and the narrow problem-solving capabilities that are promoted in higher education practices, e.g., [8]-[10].



2. OVERVIEW OF PEDAGOGY IN AN INDUSTRIAL SOCIETY VERSUS AN KNOWLEDGE SOCIETY

One of the challenging questions related to 21st century skills, is related to defining their role and place within the school curriculums. Voogt and Roblin [2] argue that 21st century skills can either be: 1) added to an already existing school curriculum as new subjects or as new content within traditional subjects; 2) integrated as cross curricular themes that place emphasis on the development of higher level competences and transversal skills or 3), a part of a new curriculum in which the traditional structure of school subjects is transformed and schools are regarded as learning organizations. However, teachers and educators should not only be knowledgeable about what 21st century competencies are about, but also understand how these skills can be cultivated through deliberate pedagogical approaches [2], [11].

Towards 21st century skills through nonlinear pedagogy

Throughout the history of schooling, the goal of teaching has been to organize what is to be learned into appropriately sized and sequenced pieces, and to arrange optimal methods of delivery [12]. This kind of pedagogy is characterized as linear [13], because the students receive the same instruction from a teacher, do some predefined exercises and then, individual student success is assessed largely in terms of their ability to reproduce what they have been taught [12], [13]. Especially the practices and conventions in higher education are often based on the idea that the task of the teacher is to transmit knowledge [14].

While in the industrial society the main focus of education was to ensure that all students acquire the same, predefined knowledge or skills, in the knowledge society, the development of 21st century skills are considered increasingly important. For the development of 21st century skills, new learning theories and modern methods call for non-linear pedagogy [13], i.e. modern methods of learning such as knowledge building [15], progressive inquiry [16], project-based learning [17], problem-based learning [18] and learning by collaborative designing [19]. Although these approaches for nonlinear pedagogy have their differences, roughly summarized, what sets these approaches apart from linear pedagogy, is that they all seem to highlight shifting the focus in education from what teachers should teach, to collaborative learning, active participation, and being able to use different tools, technologies and information resources to solve real-life problems that are very complex by nature [20]. Moreover, nonlinear pedagogy inherits the idea that a deep understanding of domain knowledge can be achieved through the exercise of 21st century skills [10]. Table 1 presents an overview of linear and non-linear pedagogy in order to clarify their similarities and differences [2][13].

ASPECTS	LINEAR PEDAGOGY	NON-LINEAR PEDAGOGY
Learning objectives	• Transmission of specific skills, knowledge or techniques • Discipline-based	• Development of 21st century skills, often realized through core subjects • Transversal, Multidisciplinary
Learning task	• Pre-defined task and solution models determined by the teacher • Apply known solutions to pre-defined problems • Individual work/homogeneous groups	• Open-ended tasks, in which solution models are determined by the learners • Create new solutions to problems that are partly ill-defined • Working in teams/heterogeneous groups
Information resources	• Pre-defined ("pushing" of knowledge)	• Open and extended ("pulling" knowledge on demand basis)
Structuring	• Scripted models of action, little variation in activities • Reproductive learning	• Adaptive structuring, many different activities • Productive learning
Scaffolding	• Elimination of errors	• On-demand scaffolding, learning through creative failures
Context	• Usually within the school	• Extends the boundaries of school learning, increases unpredictability
Assessment	• Summative assessment of outcomes	• Formative assessment during learning process

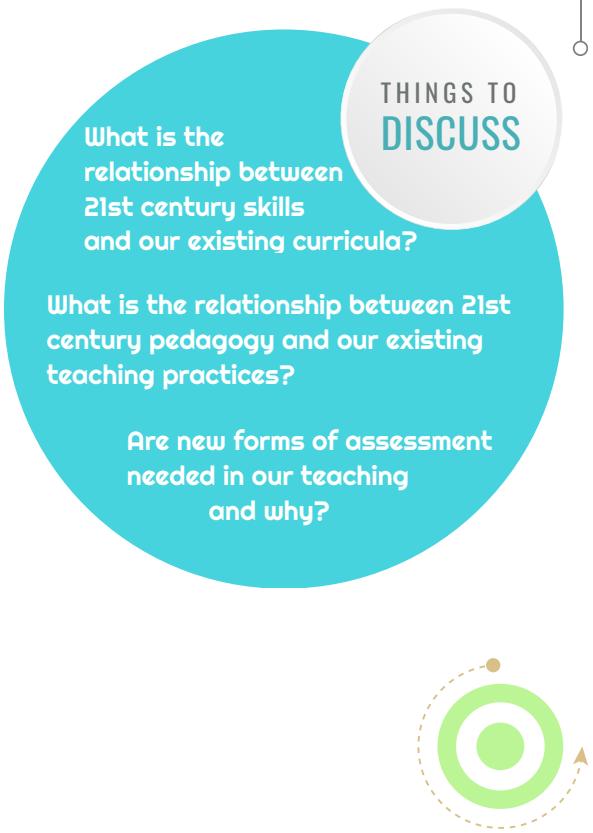
Table 1. Overview of pedagogy in an industrial society versus an knowledge society, adopted from Hakkarainen et al. [13].

In short, non-linear pedagogy appears to emphasize three main features that differ from more traditional modes of instruction. The first feature to note, is the nature of learning tasks that organize the process of learning and collaboration. In linear pedagogy, teachers typically define the task or the problem to be solved, information resources to be used and what the expected solution will look like [12], [13]. In contrast to such “closed” tasks, non-linear pedagogy is based on open-ended, multifaceted and complex problems with neither clearly defined parameters nor clear solution strategies [19]. Such complex tasks feature real-world scenarios and cannot be completed by one person. Instead, they demand collaboration as well as the use of diverse information resources [20]. In other words, the students need to articulate the problem, then search, evaluate, construct and share information, and finally apply it in the context problem-solving process at hand [18].

Secondly, non-linear pedagogy moves from individual exercises to collaborative learning that aims to mirror the process of expert problem solving processes [17]. By working together in small groups, students are expected to actively communicate, share their expertise and previous knowledge, make joint decisions as well as to negotiate roles and responsibilities [21]. In order to truly appropriate expert-like practices, students also need to work and collaborate with domain experts that are relevant in students’ future professions [22]. Through the participation in expert practices, students may begin to acquire the norms, values, and skills that shape the core identity of the expert community [22], [23], including the tacit dimension of knowing [24]. Hence, when students are working with domain experts and professionals, they may also participate in the expert practices and see how scientific knowledge can be applied to solve important, real-life problems. Accordingly, these types of non-linear projects tend to extend the boundaries of school learning [25].

The third and equally important main feature of non-linear pedagogy concerns the relations between teachers and students. While non-linear pedagogy emphasizes emergent goals and processes that are formed and modified by students in the course of pursuing them [10], teachers play a critical role in orchestrating collaborative efforts [13]. In collaborative inquiry and knowledge creation, the teacher's role is to be a facilitator that provides on-demand scaffolding in response to each group's unique project at hand [26]. This requires adaptive structures and provision of constructive feedback throughout the learning process, but also facilitation of collaboration and team working skills while generating and advancing ideas together. Sawyer [27] describes such adaptive processes of teaching and learning as collective improvisation and invention, guided by and along with the teachers. [2][13].

From the teacher's perspective, non-linear pedagogy also sets a demanding challenge to transform assessment practices to reflect the new skills and demands of knowledge society. As argued by Binkley et al. [28], 21st century skills are difficult to assess by traditional assessment methods and practices. To assess 21st century skills, there is an evident need to pair summative assessment (e.g. standardized tests at the end of a course) with formative assessment (e.g. self-assessment, peer-assessment, process portfolios). [4][10]. The primary goal of formative assessment is to make student learning and understanding visible, so that teachers are able to adapt teaching strategies to meet the student needs (i.e., assessment for learning) [2], [4]. This may be done, for example, by structuring the tasks and processes in ways that require and encourage students to share their previous knowledge as well as their evolving understanding, both with one another and with the teacher. In all, such process-oriented assessment methods may support new forms of dialogue that make students' thinking and reasoning processes visible for joint evaluation and development, thereby providing opportunities to use assessment as a means to improve teaching and learning [2], [10].



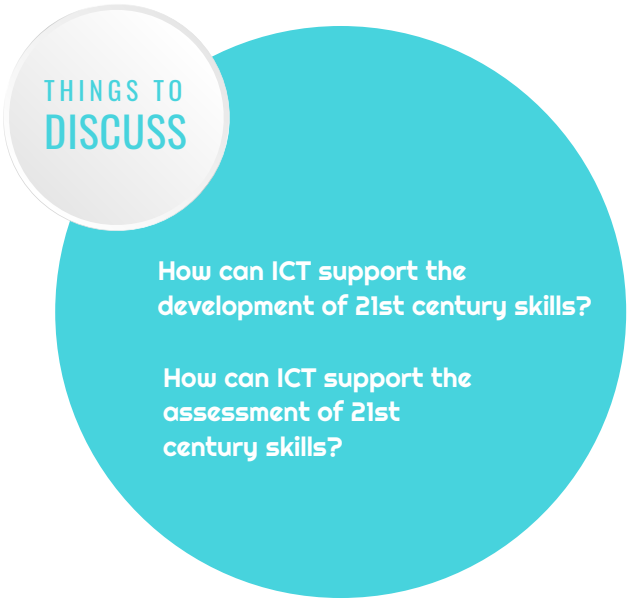
3. THE ROLE OF TECHNOLOGY IN COLLABORATIVE LEARNING

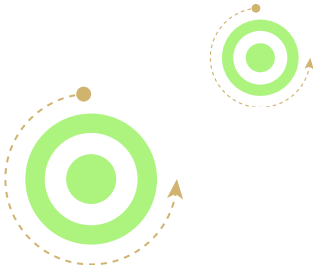
When talking about 21st century skills, many of the above discussed frameworks highlight the role of ICT. The development of technology is not only regarded as an argument for the need of new skills by all frameworks, but it is also connected to a whole new set of competences about how to effectively use, manage, filter, evaluate, and create information across different types of media [2]. According to Voogt and Roblin [2], all frameworks for 21st century skills seem to refer to the following three perspectives and skills for integrating ICT in education: 1) basic technical and operational skills needed for using, understanding, and evaluating technology (technical domain), 2) the use of ICT with a particular knowledge domain and related purpose (knowledge domain), and 3) the overall capacity to access, evaluate and use information (information literacy). From a teacher's perspective, these highlight the understanding of how different technologies may be used in specific pedagogical practices, how technology could be used to facilitate student's collaboration and knowledge creation as well as for instructing and supporting students toward a deeper understanding of the subject matter [2].

During the recent decades, different kinds of technologies have been used for supporting and triggering the activities of collaborative learning and knowledge creation. Moore, Dickson-Deane and Galyen [29] have outlined several analogous concepts, such as Learning Management Systems (LMS), Course Management Systems (CMS), Virtual Learning Environments (VLE) and Knowledge Management Systems (KMS) referring to online learning environments, such as Moodle, Optima or Blackboard. Typically, these environments contain tools for delivering and creating learning materials, areas for collaboration and communication, and tools for assessment. Currently, different cloud services like G Suite for Education by Google or Office 365 by Microsoft have also been integrated into education, providing a wide variety of tools for collaborative knowledge creation such as collaborative writing tools, forms, video-conferencing, and so forth.

Moreover, advances in learning analytics have provided new tools to explore and support some of the core processes of computer-supported collaborative learning by tracking, collecting, analyzing, and reporting data about development of students' participation, activities, and social interaction [30]-[32]. As such, these new computational methods have provided teachers and students with fundamentally new, data-driven ways to view and support the critical phases of collaborative learning, find evidence of critical moments of success or failure, and to act upon this information to improve learning and collaboration [33].

In addition to these formal online learning environments provided by schools or universities, informal learning environments and social-media tools may also provide novel channels for discussing, sharing ideas and fostering social networks [34], [35]. Today's technologies also offer ample possibilities for participating in collective knowledge creation in which people from various backgrounds can share their ideas, projects, and expertise with others [36]. For example, OpenForest-portal (www.openmetsa.fi) connects diverse experts, professionals, school communities and anyone interested, for boundary-crossing knowledge creation around forest related phenomena.



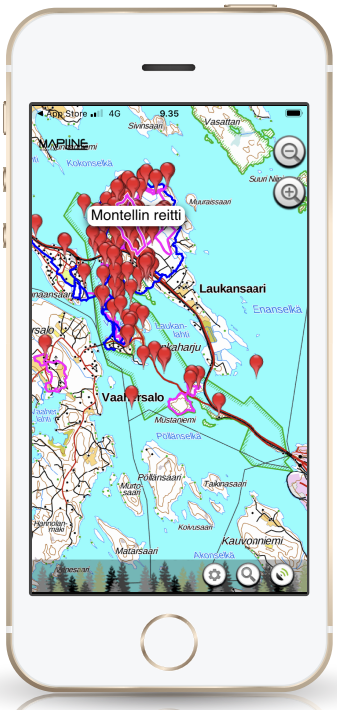


OpenForest

In Finland, forest serves both as a naturally rich environment of learning and as a boundary object motivating shared activity between diverse stakeholders. The basic idea of OpenForest is to serve as a hub that connects people from various backgrounds to share their ideas, insights and expertise around forest-related phenomena.

Originally, OpenForest evolved as a part of a joint project between University of Eastern Finland, Natural Resources Institute Finland, Finnish Forest Centre, Finnish Forest Museum Lusto and Metsähallitus. Currently, the portal has 5181 registered users and 2331 Wiki articles that are in large parts produced by experts in forest research, ecology, culture, and education. These include, for example, an introduction to research in arboretums and local areas, domain-specific models of approaching the forest phenomena, as well as representations of tools that different experts use in their work. Forest environments are also approached through various learning projects carried out in teacher training, basic education and in early childhood education.

The content of OpenForest is presented through diverse media, such as audio, image, video, and text, in any combination. For example, the portal offers a virtual trail in the Punkaharju arboretum and esker area with 360° views, as well as real-time measurement data of the provenance trials. Wiki articles can be accessed via context-aware technologies, such as accurate geographic information environment (GIS), that connect physical objects and landscapes with digital information.



www.openmetsa.fi

OpenForest portal's current development is linked to several projects including:

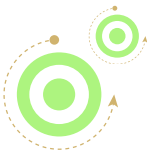
- DigiCampus
- Digifor
- Physical and Virtual Exposition of Forest Bioeconomy

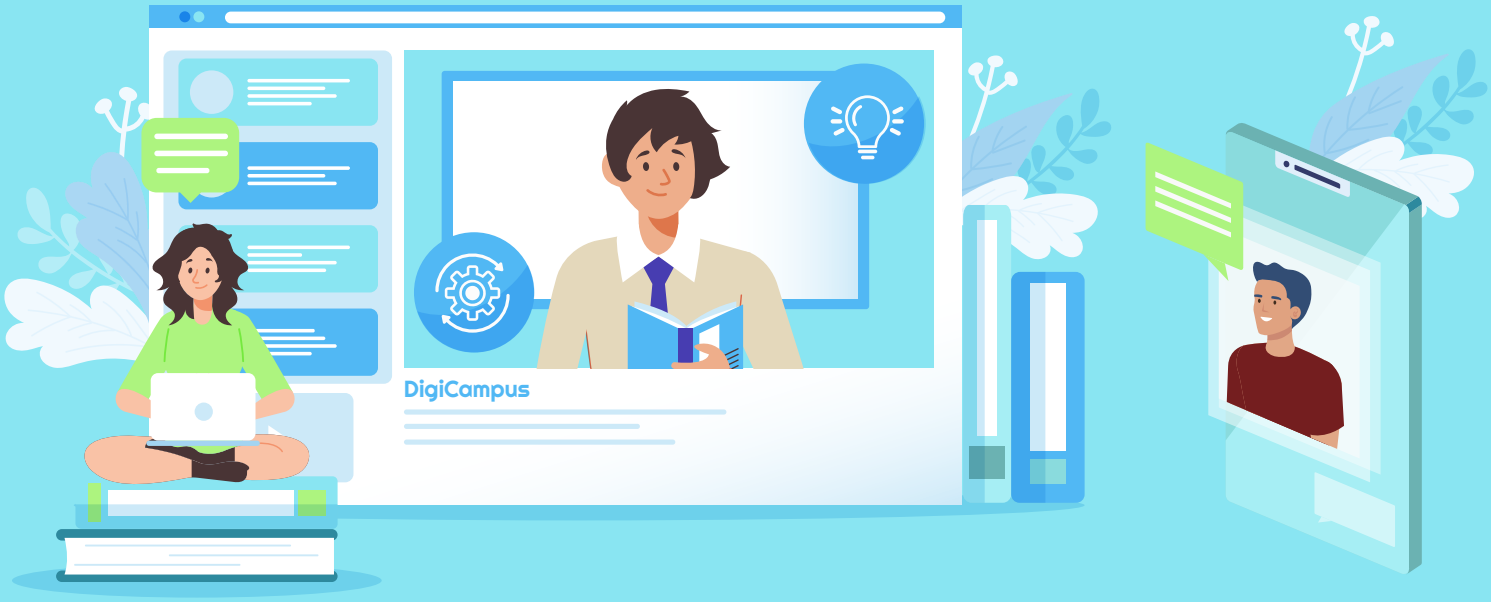
4. PROFESSIONAL DEVELOPMENT

Researchers also highlight the central role of teachers in the implementation of 21st century skills and curriculum innovations [2]. Teachers are not only expected to facilitate the acquisition of 21st century skills in their students, but teachers themselves are also required to be competent in them [5], [11]. Moreover, 21st century skills pose many challenges for teachers as they need to develop new teaching methods as well as their abilities to make use of ICT tools when supporting learning [2], [11]. While most frameworks recommend integrating 21st century skills across the curriculum, they also call for a more systematic change that provides teachers with essential institutional support to implement these reforms in practice [37].

However, previous research has shown that school reforms are often ineffective because they tend to focus on isolated elements while disregarding the sociocultural interplay of wider educational structures, cultures and practices that support and constrain teachers' professional development [37]. In reality, teachers are often working in school systems with organizational structures, practices, rituals, and beliefs, which are very different from the framework conceptualized by the new educational innovations [38]. Consequently, there is a need to build multi-professional collaboration structures between teachers, school leaders, researchers and experts for the co-development of learning environments, curriculums and pedagogies for 21st learning.

Moreover, researchers highlight the importance of promoting teachers' agency throughout the implementation of 21st century skills, starting from the discussion of their importance, to the definition of their role and place in the curriculum, as well as their implementation and assessment in practice [2]. This may be actualized, for example, by organizing in-service programs that provide teachers pedagogical, socio-emotional and technological support for co-designing and implementing boundary-crossing learning projects in their own schools [36]. Ongoing support structures should also include dialoguing sessions, in which the teachers are encouraged to reflect on their own goals and project activities as well as to share their moments of success or failure both with their peers and with researchers [36]. Such sustained collaboration is important for understanding and dealing with the contextual challenges associated with the implementation of 21st century skills and may also provide socio-emotional support needed in coping with the uncertainties and complexity of change [2], [36].





5. EXAMPLE COURSE

Hanna Vuojärvi, Miikka Eriksson & Henriikka Vartiainen

Collaborative Problem Solving in Multidisciplinary Networks

In order to support the development of higher education pedagogies that promote learning of 21st century skills, the present final chapter presents an example from an inter-university course on forest bioeconomy implemented in the summer 2019 in Finland (for further information, please see Vuojärvi, Eriksson & Vartiainen, 2020). This novel five-credit course, titled Collaborative Problem Solving in Multidisciplinary Networks, was designed by a multidisciplinary team of eight persons including teachers, researchers and experts from the fields of education, forestry and bioeconomics, during an eight month period lasting from August 2018 to March 2019. As the new course was open to students from both Universities and Universities of Applied Sciences (UAS) regardless of their discipline, the team members came from both university and UAS education backgrounds.

In short, the aim of the course was to foster higher education students' 21st century skills through collaborative problem-solving in cross-boundary teams in the context of forest bioeconomics. Two course formats were available: a blended learning version—TeamCamp—that included a three-day intensive period after the preparatory phase of the course (see Table 3) and an online version—DigiCamp—that involved no face-to-face contact. Students were free to choose between blended and online course options. The course design was based on nonlinear pedagogy and informed by the framework of 21st century skills provided by Binkley et al.[4].

During the 11-week course, students completed altogether eight assignments. Each assignment had to be completed successfully before students could move on to the next one. Table 2 presents the overall design and organization of the course including the assignments.

Table 2. The course design

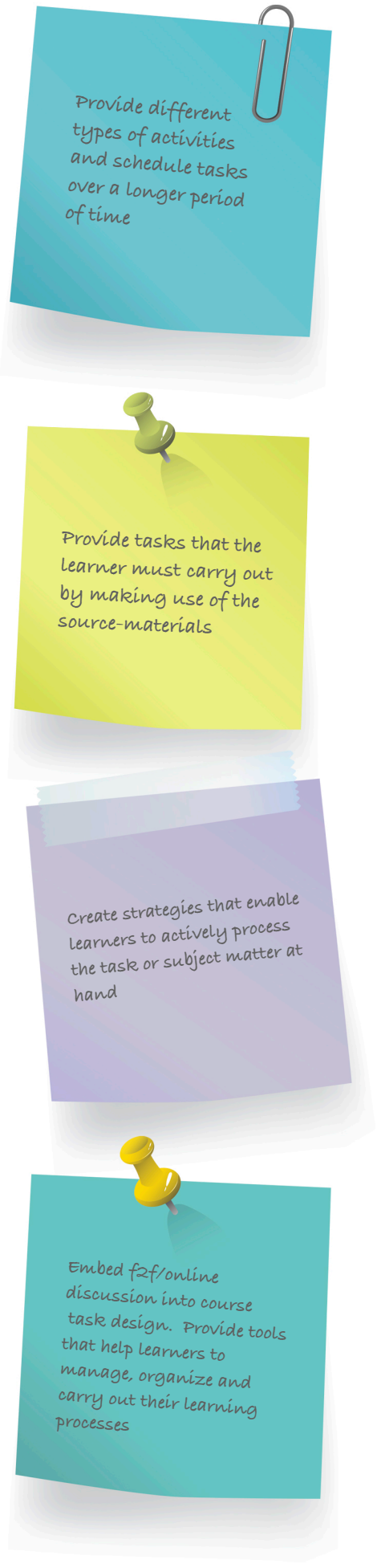
Description of assignments and activities students engaged in	Learning objectives 21st century skills proposed by Binkley et al. (2012) are bolded	Interaction with teachers
Preparatory assignments (1–4) 1. Provide introductions through FlipGrid videos.	To develop oral **communication** skills via video introductions.	Feedback if needed.
2A. Determine perceptions of the skills and knowledge needed in the field of forest bioeconomics. 2B. Present students' learning objectives.	To develop **metacognition** by setting goals (**life and career**) and completing a self-evaluation at the end of the course.	Teacher accepts or rejects the submission. Feedback if needed.
3A. Familiarise students with the field of forest bioeconomics through the provided materials. 3B. Formulate five questions about the forest bioeconomy.	To develop **multiliteracy** by managing information from various sources and engage in **critical thinking** and **problem-solving** by asking personally meaningful questions.	May follow students' activity during step A via DigiCampus. Teacher accepts or rejects submission.
4. Interview a forest bioeconomics professional about the company's operations related to a forest bioeconomy and the key knowledge and skills needed in the field.	To develop the ability to interact with professionals in the forest bioeconomics field (**life and career**).	Teacher accepts the subject of the interview. Assignments submitted to a discussion forum. Possibility for interaction and feedback.
Development challenge (5–6) 5A. Negotiate the rules of collaboration for your team. 5B. Choose the ten most interesting questions from the pool of questions created for assignment 3. 5C. Categorise the chosen questions with one's team to find a common theme of interest. 5D. Formulate a development challenge for the team. 5E. Take advantage of scientific research and expert knowledge to develop an executable solution for the challenge.	To develop the ability to **collaborate**; **communicate**; and use technologies and social networks to search, organise, evaluate, create and communicate information (**multiliteracy**). To become willing to leverage others' strengths to accomplish a common goal, understand strategies for tackling ill-defined problems and base decisions on evidence (**critical thinking, problem-solving and decision-making**).	TeamCamp: Interaction with teachers possible during the whole process of teaming and formulation of the development challenge. DigiCamp: Interaction with teachers possible during the process of teaming through the team's discussion forum and email. Teacher provides feedback on submitted report through the team's discussion forum.
6. Prepare a short pitch about the team's solution using FlipGrid.	To develop **communication** skills by presenting results in the form of a video.	Feedback if needed.
Assessment (7–8) 7. Perform peer assessments based on other teams' pitches created using FlipGrid.	To develop **personal and social responsibility** by learning to provide constructive feedback in a professional manner.	Feedback if needed.
8. Perform self-assessment and reflect on the learning objectives and process of working in a team.	To develop **metacognition** and the **ability to learn** by reflecting on the objectives of learning.	Feedback if needed.

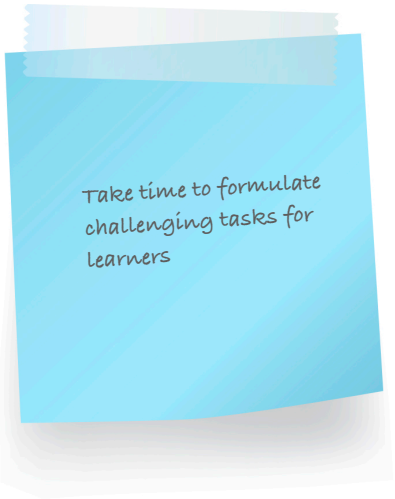
The first four assignments were preparatory assignments that students completed individually. Their objective was to introduce students to one another and present an overview of the field and basic concepts of bioeconomics. As a support on the preparatory assignments, various materials, including instructions and introductions, were provided through a virtual learning environment (VLE) called DigiCampus. The materials took the form of video lectures by teachers, introductory videos by experts of different sectors of bioeconomics, articles, and lists of references. The participating teachers introduced themselves in videos via FlipGrid application.

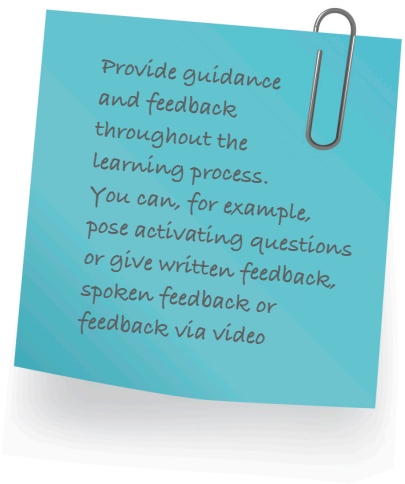
During the preparatory assignments, teachers were tasked with monitoring students' efforts, accepting or rejecting students' submissions and giving feedback when needed. Teachers were able to follow students' progress on DigiCampus VLE. In the preparatory assignment 4, that featured an interview of a forest bioeconomics professional, teachers accepted or rejected the interview subject, and in cases of rejection, guided students towards a more suitable interviewee.

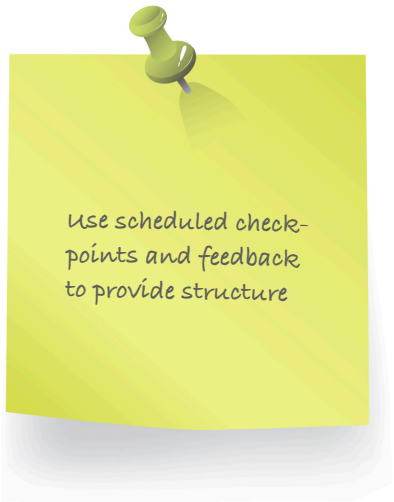
The assignments 5 and 6 served as the core of the course, providing a development challenge to be completed in cross-boundary teams formed by the teachers. The formation of the teams was mainly based on the students' primary disciplines, but their former studies and work history were also considered in order to compose as heterogeneous groups as possible.

The teams were provided with private discussion forums on DigiCampus VLE for asynchronous communication and with a chat room for synchronous communication, but they were also encouraged to use any suitable applications to make interaction as effortless as possible. The teams were also encouraged to actively interact with the participating teachers or other experts they believed could help them complete their development challenge. Throughout the course, students had access to the materials provided for the preparatory assignments, but they also had to search for and choose additional materials suitable for their work. When starting to work on the development challenge assignments, the teams were required to agree on the rules for their work (assignment 5A) and post them on the discussion forum in the DigiCampus VLE to ensure that strategies were in place to deal with possible conflicts or disagreements.









For assignment 5B, each student chose ten interesting questions about forest bioeconomics from the pool of questions to which all participating students contributed during preparatory assignment 4. Next, the chosen questions were categorised and analysed by each team to formulate a common development challenge (i.e. an ill-defined question). Teams were tasked with developing solutions to these challenges that could be operationalised, required research-based knowledge and utilised modern technology. The teams had to prepare a written report as well as a five-minute video pitch for their solution using FlipGrid.

Following the 21st century skills framework of Binkley et al.[4] and the pedagogical starting points presented above, the idea of the development challenge assignments (5 and 6) were to engage students in a co-creative process that entails (1) communicating and collaborating in cross-boundary teams with people of different backgrounds, (2) using digital technologies and social networks to promote teamwork (3) developing multiliteracy and critical thinking skills by making students search for, organise and evaluate information; (4) basing decisions on evidence; (5) make their process visible through communicating information within their teams and to teachers and other students (6) being flexible and willing to consider others' ideas and ways of working; and (7) identifying and leveraging others' strengths to accomplish a common goal.

During the development challenge phase, teachers created the cross-boundary teams and re-assigned students in case of dropouts, which happened only in the DigiCamp course. Teachers were also involved in helping teams formulate their development challenges, and they had to accept the topic of each challenge before the teams could move on. For teams within the TeamCamp course, this interaction that made students' and teams' processes visible to teachers took place face-to-face. For teams within the DigiCamp course, interaction took place in discussion forums within the DigiCampus VLE or via email. If DigiCamp teams needed help, teachers clarified the instructions. At the end of the development challenge phase, teachers gave feedback to the teams about their pitches and reports. The TeamCamp teams participated in a feedback session via Skype for Business, and the DigiCamp teams received feedback through their discussion forums in the DigiCampus VLE.

The last two assignments of the course concerned assessment. Each student assessed and wrote a one-page analytic summary of the other teams' pitches. To assess their own performance and learning within the course, students reflected on the learning objectives they set at the beginning of the course and how they worked in their teams. The objective of this phase was to develop students' personal and social responsibility by teaching them to provide constructive feedback in a professional manner and to help them develop metacognition and the ability to learn by reflecting on learning objectives. In addition, it taught students how to reflect on the process of working in cross-boundary teams, analyze changes in their thinking and consider how these changes may affect their working processes in the future. Teachers accepted or rejected these submissions and gave feedback when needed.

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